

AMENDMENT TO THE CLAIMS

1. (Currently Amended) A method for optically determining a physical attribute of an object moving along a defined path, the method comprising the steps of:

fixing one or more cameras, each camera being located to view the object when the object is at a trigger location;

fixing one or more fanned lasers, each laser being located outside the path and projecting a laser beam along its laser plane onto the object when the object is at the trigger location, the intersection of the laser plane with the object at the trigger location being visible by at least one of the cameras;

optically establishing a mathematical spatial relationship between the cameras and the plane of each of the laser beams;

creating a pixelated image of the object in one or more of the cameras illuminated by the planar laser beams when the object is at the trigger location;

selecting at least one pixel location in each image, the at least one pixel location corresponding to a point on the object illuminated by a laser beam;

for each of the selected pixel locations, using the mathematical spatial relationship to establish the three dimensional position of the point based on the two dimensional position of the pixel location;

using the three dimensional position of the respective point to determine the physical attribute of the object;

wherein optically establishing a mathematical spatial relationship further comprises:

establishing an orientation and location of each camera with respect to a co-ordinate system;

establishing an orientation of each laser plane within the co-ordinate system;

and

deriving a transformation function for calculating the three dimensional position of points within the plane of each respective laser beam from the pixel location within a pixelated image; and,

wherein establishing an orientation and location of the camera further comprises:

temporarily mounting a calibration device having at least six non-collinear visible markings at known points on at least two non-parallel surfaces of the calibration device, the calibration device being positioned in the path

and in view of each camera at a reference position such that each camera can view the at least six points;

for each camera, creating a first pixelated image of the calibration device; and
using the known position of the at least six markings relative to the co-ordinate system and the pixel locations within the first image to establish a transformation equation between pixel locations and the three dimensional co-ordinates of the calibration device at the reference position.

2. (Canceled)
3. (Canceled)
4. (Currently Amended) A method according to claim 3 1, wherein establishing an orientation of each laser plane within the co-ordinate system further comprises:
illuminating the calibration device with each laser beam to form a line along the surface of the calibration device;
for each camera, creating a second pixelated image of the calibration device;
and
using the position of at least three non-collinear points within the line relative to the co-ordinate system and the pixel locations corresponding to the positions of the points within the second image to establish an equation defining the orientation of the laser.
5. (Original) A method according to claim 4, wherein the second pixelated image is the first pixelated image.
6. (Previously Presented) A method according to claim 1, wherein a pixel location is defined to sub-pixel accuracy using image analysis techniques.
7. (Currently Amended) A method according to claim [3] 1, wherein the reference position is the trigger location.
8. (Currently Amended) A method according to claim [3] 1, wherein the two surfaces are planar and at least two points are located on each of the two surfaces.

9. (Currently Amended) A method according to claim [3] 1, wherein the two surfaces are orthogonal.

10. (Currently Amended) An optical method for determining a physical attribute of an object moving along a defined path, the method comprising:

fixing at least one fanned laser at a position outside of the path to project its laser beam onto the moving object when the moving object is at a trigger location;

fixing at least one camera at a location to view the moving object when illuminated by the laser beam at the trigger location, each camera producing a digital image comprising an array of pixels;

forming a calibration device comprising two planar surfaces which intersect in a line forming an edge of the device and, at least six non-collinear visible points on the planar surfaces at known locations on the calibration device defining a calibration co-ordinate system;

temporarily mounting the calibration device in the path in view of the at least one camera, and where illuminated by the at least one fanned laser;

producing an image of the device on each camera and determining for each of one or more pixel locations within the image an equation in terms of the calibration co-ordinate system, of a ray passing through a centre of lens of the camera which, when projected onto the device coincides with the pixel location;

determining an equation of a plane in the calibration co-ordinate system containing the fanned laser beam;

removing the calibration device;

taking an image of the object when illuminated by the at least one laser beam at the trigger location and utilising the laser plane equations, determining a three dimensional location in the calibration co-ordinate system of selected pixel locations of the object illuminated by the at least one laser, and from the three dimensional locations determining physical attribute of the object;

wherein forming the calibration device further comprises providing a third planar surface having a first edge coincident with an edge of the first planar surface distant the second planar surface, and a fourth planar surface having a first edge coincident with an edge of the third planar surface distant the first planar surface, and a second edge coincident with an edge of the second planar surface distant the first planar surface.

11. (Original) An optical method according to claim 10, wherein forming the calibration device further comprises arranging the first and second planar surfaces at right angles to each other.
12. (Canceled)
13. (Currently Amended) An optical method according to claim [12] 10, wherein the second and third planar surfaces are parallel to each other and the first and fourth planar surfaces are parallel to each other.
14. (Previously Presented) An optical method according to claim 10, wherein fixing the at least one fanned laser comprises fixing two or more fanned lasers at respective locations outside of the path whereby the laser beams from each laser projects onto the moving object at different locations.
15. (Previously Presented) An optical method according to claim 10, wherein fixing the at least one camera comprises fixing two or more cameras such that each camera is able to view the intersection of at least two laser beams with an object at the trigger location.
16. (Previously Presented) A method according to claim 10, wherein a pixel location is defined to sub-pixel accuracy using image analysis techniques.
17. (Currently Amended) A method for optically establishing a mathematical spatial relationship between one or more cameras and one or more fanned lasers each capable of projecting a laser beam along a laser plane, the method comprising:
 establishing an orientation and location of each camera with respect to a co-ordinate system;
 establishing an orientation of each laser plane within the co-ordinate system;
 and
 deriving a transformation function for calculating the three dimensional position of points within the plane of each respective laser beam from a pixel location within a pixelated image created by each of the cameras;
wherein establishing an orientation and location of each camera further comprises:

temporarily mounting a calibration device having at least six non-collinear visible markings at known points on at least two non-parallel surfaces of the calibration device, the calibration device being positioned in the path and in view of the cameras at a reference position such that each camera can view the at least six points;

for each camera, creating a first pixelated image of the calibration device; and using the known position of the at least six markings relative to the co-ordinate system and the pixel locations within the first image to establish a transformation equation between pixel locations and the three dimensional co-ordinates of the calibration device at the reference position; and wherein establishing an orientation of each laser plane within the co-ordinate system further comprises:

illuminating the calibration device with each laser beam to form a line along the surface of the calibration device;

for each camera, creating a second pixelated image of the calibration device; and

using the position of at least three non-collinear points within the line relative to the co-ordinate system and the pixel locations corresponding to the positions of the points within the second image to establish an equation defining the orientation of the laser.

18. (Canceled)

19. (Canceled)

20. (Currently Amended) A method according to claim [19]17, wherein the second pixelated image is the first pixelated image.

21. (New) An optical method for determining a dimension or orientation of an object moving along a defined path, the method comprising:

fixing at least one fanned laser at a position outside of the path to project its laser beam onto the moving object when the moving object is at a trigger location;

fixing at least one camera at a location to view the moving object when illuminated by the laser beam at the trigger location, each camera producing a digital image comprising an array of pixels;

forming a calibration device comprising two planar surfaces which intersect in a line forming an edge of the device and, at least six non-collinear visible points on each of the planar surfaces at known locations on the calibration device defining a calibration co-ordinate system;

temporarily mounting the calibration device in the path at a fixed position and in view of the at least one camera, and where illuminated by the at least one fanned laser;

producing an image of the calibration device on each camera and determining for each of one or more pixel locations within the image a ray equation in terms of the calibration co-ordinate system, of a ray passing through a centre of lens of the camera which, when projected onto the device, coincides with the pixel location;

illuminating the calibration device by the or each fanned laser to produce for each laser a line on each of the two planar surfaces;

taking an image of the laser illuminated calibration device and from this determining a laser plane equation in the calibration co-ordinate system containing the fanned laser beam;

removing the calibration device; and,

taking an image of the object with the or each camera when illuminated by the at least one laser beam at the trigger location and utilising the ray equations and the laser plane equations, determining a three-dimensional location in the calibration co-ordinate system of selected pixel locations of the object illuminated by the at least one laser, and from the three-dimensional locations determining the dimension or orientation of the object.

22. (New) The method according to claim 21, wherein determining the dimension or orientation of the object comprises selecting at least one pixel location from two or more different parallel planes on the object.

23. (New) The method according to claim 21, wherein fixing at least one fanned laser and fixing at least one camera comprises fixing the or each camera at a different height to each of the at least one fanned laser.

24. (New) The method according to claim 21, wherein fixing at least one fanned laser and fixing at least one camera comprises fixing the or each camera in a manner so that a ray passing through an origin of a lens of the camera is not parallel to a plane containing the fanned laser beam of any of said at least one fanned laser.

25. (New) An optical method according to Claim 21, wherein forming the calibration device further comprises arranging the first and second planar surfaces at right angles to each other.

26. (New) An optical method according to Claim 21, wherein fixing at least one fanned laser comprises fixing two or more fanned lasers at respective locations outside of the path whereby laser beams from each laser projects onto the moving object at different locations.

27. (New) An optical method according to Claim 26, wherein fixing at least one camera comprises fixing two or more cameras such that each camera is able to view an intersection of at least two laser beams with an object at the trigger location.

28. (New) A method according to Claim 21, wherein the selected pixel locations are defined to sub-pixel accuracy using image analysis techniques.

29. (New) A method according to Claim 21 wherein the fixing at least one formed laser comprises fixing two or more fanned lasers at respective positions where the fanned lasers project their respective laser beams onto the object from opposite directions; and wherein the fixing at least one camera comprises fixing cameras at location to view the laser beams projected onto the object from the opposite direction; and wherein forming the calibration device further comprises providing a third planar surface having a first edge coincident with an edge of the first planar surface distant the second planar surface, and a fourth planar surface having a first edge coincident with an edge of the third planar surface distant the first planar surface, and a second edge coincident with an edge of the second planar surface distant the first planar surface,

wherein said third and fourth surfaces defining a second calibration co-ordinate system having a known spatial relationship relative to the calibration co-ordinate system.

30. (New) An optical method according to claim 29, wherein the second and third planar surfaces are parallel to each other and the first and fourth planar surfaces are parallel to each other.